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APPLICATION OF THERMAL ACTUATOR

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Abstract: A 3-D MEMS electrothermal microgripper has been designed and simulated using COMSOL 4.2a. Electrothermal mechanism is the most widely used mechanism for providing large displacements at low voltage. The gripper presented here is geometrically optimized to explore the effect of dimensional variation on its performance. Length of the hot arm and gap between the hot and cold arm is varied.

Keywords: MEMS, Electrothermal Actuator,Joule Heat, Thermal Expansion.

1. INTRODUCTION

Micro-grippers find applications in microrobotics, microsurgery, micro-fluidics, microrelays,assembling and miniature medical instrumentation. Actuation principle involved may be electrothermal, electrostatic, piezoelectric, shape memory and electromagnetic. It has been found that thermal actuation provides greater displacement at low voltages when compared to other mechanisms. Micro-gripper is comprised of two microactuators (hot-and-cold-arm actuator) which operates on the basis of Joule heating and thermal expansion. The hot-and-cold arm actuator consists of one narrow (hot) arm, one wide (cold) arm and the flexure. Flexure joins the wider arm with the anchor as shown in figure 1. When voltage is applied in series to this structure, the current will flow through these arms with same heat distribution. Thus the narrower arm gets more heated due to small resistance according to the relations; R=ρL/A and H=I2R, where R is the resistance, L is the length and A is the area of cross section of the arm, H is the Joule heat produced in the arm and I is the current flowing through the arm. As a result of more heated narrower arm, it will deflect more than wider arm. Thus, the narrower arm creates mechanical force and pushes the structure in direction narrower to wider arm. Also,when the voltage is applied in parallel, then the structure bends in opposite direction.

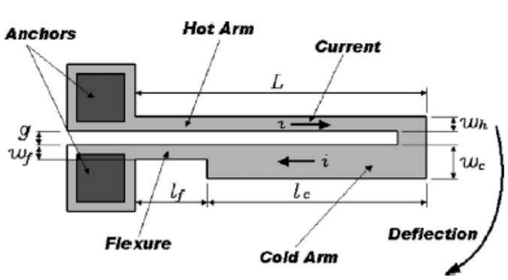

Figure1: Design of Thermal Actuator

2. DESIGN CONCEPT

Thermal microactuators are a promising solution to the need for large displacement, low-power MEMS actuators. The two arms of the gripper are of different length. The whole structure is made up of polysilicon as it is compatible with IC technology. The initial dimensions of the microgripper are as given in the table 1 and its design is shown in figure 2.

Dimension	Value
Length of the hot arm (Lh)	500μm
Width of the hot arm (Wh)	2.5μm
Length of the cold arm (Lc)	440μm
Width of the cold arm (Wc)	10μm
Length of the flexure (Lf)	60μm
Width of the flexure (Wf)	2.5μm
Gap between the arms (g)	5μm

Table 1: Dimensions of the Microgripper

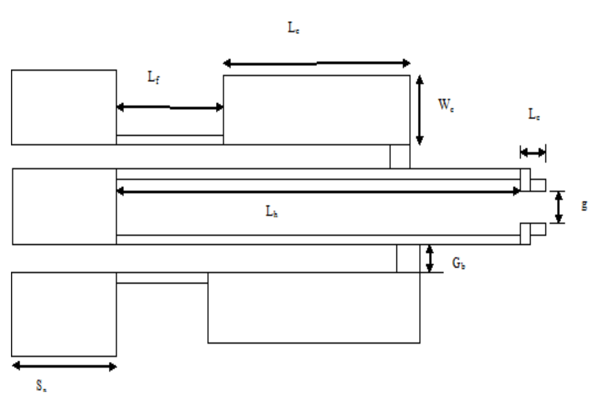

Figure 2: Design of Microgripper

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3. FEM Simulation

The microgripper is designed and simulated in MEMS module of COMSOL Multiphysics 4.2a. According to the principle discussed in section I, the narrow arm gets more heated than the wider arm as shown in figure 3.

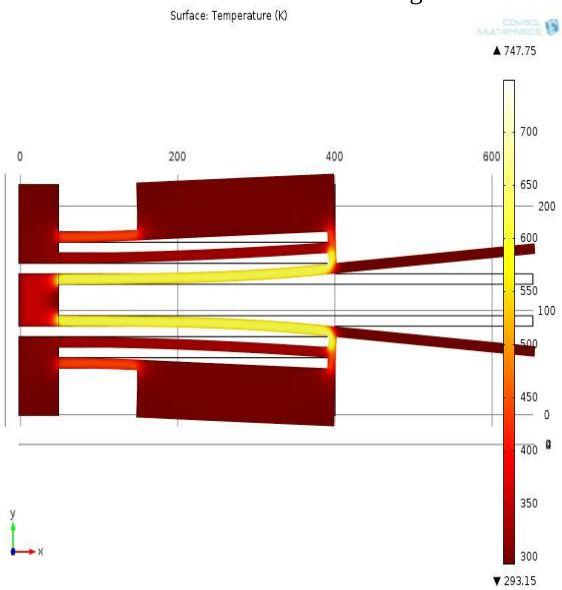

Figure 3: Temperature Profile

It is clearly shown in above figure that the gripping arms remain at room temperature which is one of the main advantage of this design. The maximum temperature lies in the middle of the hot arm i.e., 747.75K and displacement at the tip is 17.882µm at 3V as shown in figure 4.

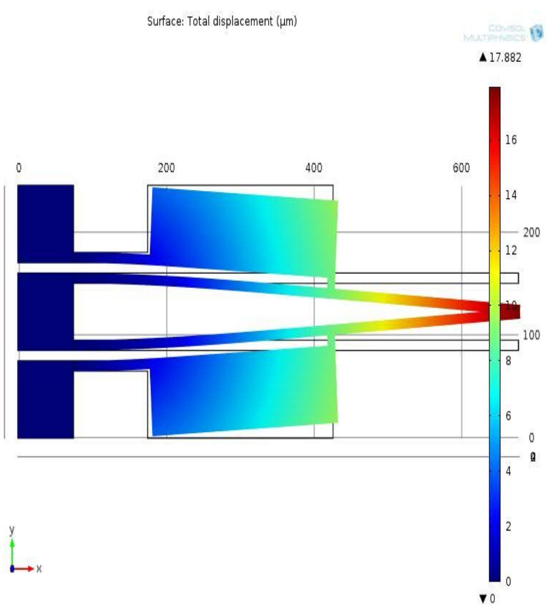

Figure 4: Displacement

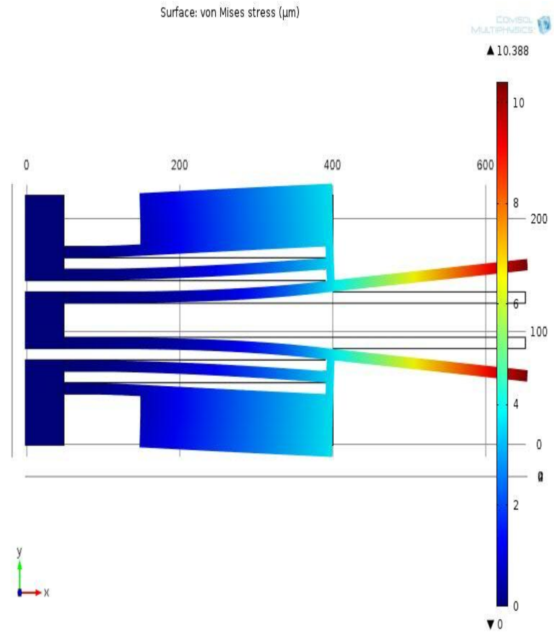

Figure 5: Stress Profile

4.GEOMETRICAL OPTIMIZATION

The microgripper is geometrically optimized for improvement in its performance. The length of the hot arm is varied from 600µm to 500µm. With 600µm hot arm, displacement at 3V is 7.7µm, when length of the hot arm is 500µm displacement is increased to 17.882.this is because the gap between the arms (i.e between hot and cold arm) is reduced from 10 to 5µm as shown in table 2.

Table 2: Variation of Displacement with L_h

Length of the hot arm(µm)	Displacement(µm)
600	7.7
500	17.882

Table 3: Variation of Displacement with Gb

Gap between the arms(µm)	Displacement(µm)
10	7.7
5	17.882

The gap between the arms (G_b) is also varied from 10µm to 5µm. On decreasing the gap, the displacement increases. As the length of the hot arm is increased the displacement will be more as shown in table 3.

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5. Conclusion and Future Scope

The result concludes that the electrothermal actuator is highly sensitive to geometrical variations. It has been realized that longer hot arms produce more deflections but a tradeoff lies in the sense that, on increasing the length of the hot arm, resistance also increases, so there is a chance of failure due to stiction to the substrate. On decreasing the gap between the beams of the actuator, tip displacement increases. Thus it is desired to use longer hot arms, narrower gaps between the beams, optimum flexure and cold beams and wider cold beams to produce more deflections. Wider hot beams will decrease the displacements. The geometrical variations in the actuator increases the displacement at the tip significantly but the maximum temperature in the actuator is less sensitive to the geometrical variations. The main advantage of this U-beam design is that single material is used. Thus, these designs are easy to fabricate and provides large displacements even at smaller applied voltages. Also different materials can be used like polymers, as they are non conductive, these can be used for the microgrippers in biomedical applications. Metals can also be used as they are more conductive than Polysilicon, these can result in more displacements. The arrays of these types of actuators can be used for various applications like in switching applications, stepper motor.

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